PATENT ABSTRACTS OF JAPAN

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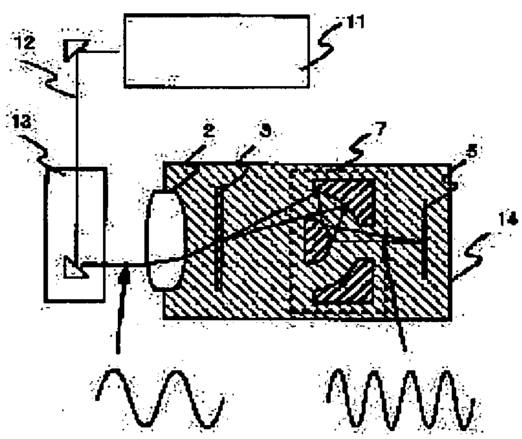
(71)Applicant : HITACHI LTD
(72)Inventor : FUKUDA HIROSHI
TANAKA TOSHIHIKO

(54) PATTERN FORMING METHOD AND EXPOSURE APPARATUS THEREFOR

(57)Abstract:
PURPOSE: To improve resolution by forming a projection optical system of an optical system having a reflection type lens, and fully filling entirety or part of an optical path of the projection system included between a surface of a board and the projection system with medium having 1 or more of specific refractive index to the air in the wavelength of a light.
CONSTITUTION: A beam 12 generated from a KrF excimer laser 11 is emitted to a mask 3 via a beam shaping optical system 13 and an illumination optical system 2. A light passing through the mask 3 is exposed on a board 5 via a reflection type contraction projection lens 7. The lens 7 is a Schwarzschild type optical system having a numerical aperture of 0.3 to focus the mask 3 on the board 5. The entire system from the irradiating side of the illumination system to the board via the mask is installed in a liquid vessel 14, and water is fully filled in the vessel to fill the water in the optical path. Then, a pattern is transferred to a positive resist film coating the Si board by using a projection exposure apparatus to form a 0.35μ mL/S pattern.



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CLAIMS

[Claim(s)]
[Claim 1] In the approach of forming a pattern on the above-mentioned substrate by irradiating at a mask the light which emitted the light source through an illumination-light study system, and carrying out image formation of the pattern on the above-mentioned mask to up to a substrate according to projection optics The pattern formation approach characterized by filling with a medium with the bigger rate of specific refraction to the air in the wavelength of the above-mentioned light than 1 the whole optical path or a part of the above-mentioned projection optics which constitutes the above-mentioned projection optics according to the optical system containing a reflective mold lens, and includes between the above-mentioned substrate and the above-mentioned projection optics at least.
[Claim 2] It is the pattern formation approach that the above-mentioned medium is a liquid in claim 1.
[Claim 3] It is the pattern formation approach that the wavelength of the above-mentioned light is 150-250nm in claim 2.
[Claim 4] In the aligner used in case a pattern is formed on the above-mentioned substrate by irradiating at a mask the light which emitted the light source through an illumination-light study system, and carrying out image formation of the pattern on the above-mentioned mask to up to a substrate according to projection optics The projection aligner characterized by filling with a medium with the bigger rate of specific refraction to the air in the wavelength of the above-mentioned light than 1 the whole optical path or a part of the above-mentioned projection optics which constitutes the above-mentioned projection optics according to the optical system containing a reflective mold lens, and includes between the above-mentioned substrate and the above-mentioned projection optics.
[Claim 5] The projection aligner which forms a transparent septum between the above-mentioned projection optics and said substrate, and divides the above-mentioned medium into an optical-system and substrate side in claim 4.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the pattern formation approach for forming the detailed pattern of various solid-state components, and the projection aligner used for this.
[0002]
[Description of the Prior Art] In order to improve the degree of integration and working speeds of a solid-state component, such as LSI, detailed-ization of a circuit pattern is progressing. The reduced-projection-exposure method excellent in mass-production nature and definition ability is widely used for such pattern formation now.
[0003] The optical system of a reduced-projection-exposure method is typically shown in drawing 2 (b). The light which emitted the effective light source 1 on a secondary surface of light source is irradiated by the mask 3 through the illumination-light study system 2, and image formation of the light diffracted with the pattern on a mask 3 is carried out on a substrate 5 with the contraction projection lens 4. What a contraction projection lens usually becomes from the combination of a refraction mold lens is used. Since the resolution limit of this approach is proportional to exposure wavelength and it is in inverse proportion to the numerical aperture (NA) of a projection lens, improvement in the resolution limit has been performed by a raise in NA, and short wavelength-ization. Conventionally, after 64-megabit DRAM, the circuit dimension became smaller than the wavelength of light, and exposure light has reached the physical limitation, although g line (wavelength of 436nm) of a high-pressure mercury lamp and i line (wavelength of 365nm) have been used.
[0004] as the approach of on the other hand increasing effectual NA of the optical system of a microscope etc. -- immersion (oil immersion) -- law is known. By being filled up with the liquid (an oil usually being used) which has the bigger refractive index n than air between the tip of a lens, and a sample, this approach sets wavelength of light to 1/n effectually, and raises resolution. The application to the optical lithography of this approach is discussed by for example, the collection of the 53rd Japan Society of Applied Physics academic lecture meeting lecture drafts, the 2nd separate volume, and the 472nd page (1992).
[0005] On the other hand, the approach using reflective mold projection optics, such as a step and a scanning method, as another gestalt of the projection aligner for optical lithographies is examined. It is not based on wavelength but this optical system is a maximum of 0.7. To NA with big extent, implementation is made possible and it is very promising as a future aligner. In this method, although a refraction mold optical element is used for a part, since chromatic-aberration amendment is possible, it exposes in the comparatively large wavelength field of 245-253nm of a xenon mercury lamp. For this reason, stabilization of wavelength is not needed by any means with narrow-band-ization of a precise laser wavelength spectrum like a excimer laser stepper using the conventional full refraction mold optical system, and multiplex cross protection and the standing wave effectiveness can be reduced. Moreover, it is the practical big features that exposure area is also large.
[0006] The optical system of a step and a scanning method is discussed by the 14th page from the 12th page (TECHNICAL INFORMATION INSTITUTE, Tokyo, 1991) of a resist ingredient process technique.
[0007]
[Problem(s) to be Solved by the Invention] By the way, refraction mold objective lenses, such as a microscope used with the above-mentioned conventional immersion method, are designed by dedication on the assumption that it is filled up with the liquid of a predetermined refractive index between a lens tip and a sample. The same of this situation is said of the case of the lens for projection exposure, and it is necessary to design the projection lens corresponding to immersion specially as an exclusive lens with a design which is completely conventionally different from a lens. Here, suppose that the liquid restoration field 6 (drawing

2 (b) shadow area) between the tip of conventional-type dioptric lenses other than for immersion and a substrate (or sample) was temporarily filled up with the liquid of a refractive index n. In this case, although wavelength is effectually set to 1/n, in order that the angle of refraction in a lens tip may decrease according to a Snell's law, the optical path of a beam of light changes like the broken line of drawing 2 (b), and effectual NA decreases. For this reason, resolution does not necessarily improve. And there was a problem that it was very difficult to reconcile with big NA peculiar to an immersion lens a large exposure area demanded in the lens for steppers.

[0008] It is desirable to shorten exposure wavelength as much as possible on the other hand, in order to improve the resolution of optical lithography further. However, both the exposing method by conventional-type dioptric system and the reflective mold projection exposing method had the problem that ArF excimer laser (wavelength of 193nm) will become the limitation of practical short-wavelength-izing from the limitation of the permeability of an optical material.

[0009] It is to offer the pattern formation approach which can be improved to a limit in the resolution of the projection exposing method, the purpose of this invention acquiring the improvement effectiveness in resolution equivalent to having short-wavelength-ized effectually simple, and securing a large exposure field, without changing greatly the configuration and optical system of an aligner of a conventional type.

[0010]

[Means for Solving the Problem] In the approach of forming a pattern on the above-mentioned substrate by this invention's irradiating at a mask the light which emitted the light source through an illumination-light study system, and carrying out image formation of the pattern on the above-mentioned mask to up to a substrate according to projection optics, in order to attain the above-mentioned purpose The optical system containing a reflective mold lens constitutes the above-mentioned projection optics, and the whole optical path or a part of the above-mentioned projection optics which includes between the above-mentioned substrate and the above-mentioned projection optics at least is filled with a medium with the bigger rate of specific refraction to the air in the wavelength of the above-mentioned light than 1.

[0011]

[Function] It considers changing the refractive index of the medium which fulfills the whole optical path of the catoptric system shown in drawing 2 (a). Drawing 2 (a) transposes the refraction mold contraction projection lens 4 in drawing 2 (b) to the reflective mold contraction projection lens 7. In drawing 2 (a), the continuous line and the dotted line showed respectively the optical path of a beam of light when the refractive index of a medium is small, and the optical path of the beam of light in the case of being large. The optical path in catoptric system is decided only by the shape of surface type of a reflective lens according to the law of reflection, and is not based on the refractive index of a medium. Therefore, even if it changes the refractive index of a medium, the geometrical optics-property of optical system, such as numerical aperture, does not change at all. On the other hand, if the matter of the rate n of specific refraction to a vacuum is used as a medium, wavelength will be effectually set to 1/n. Consequently, effectiveness equal to only wavelength having become short substantially is acquired. in addition -- although perfect catoptric system was assumed and explained by drawing 2 (a) since it was easy -- partial -- dioptric system -- business -- a potato is good.

[0012] Moreover, a medium is 1.2, in order that it may be desirable for the refractive index to exposure wavelength to be large as much as possible and it may acquire sufficient resolution effectiveness. It is desirable that it is above. Moreover, it is substantially transparent to exposure wavelength, and it is desirable not to have a bad influence on an optical element and a resist. Specifically, organic solvents, such as water or alcohol, and a straight chain hydrocarbon, silicone resin, the liquid that dissolved the inorganic compound or the organic compound in these further, the various liquids currently conventionally used in an immersion microscope, the immersion method of determination of index of refraction, etc. can be used.

[0013] In addition, since there is a possibility of having a bad influence on the image formation property of optical system when a refractive index changes with fluctuation of the temperature of a medium, a consistency, etc. in optical system, as for these temperature etc., controlling carefully is desirable. Since a substrate is especially scanned to optical system by scan optical system, it is desirable to take care so that an image formation property may not change with the flow of a medium.

[0014]

[Example]

(Example 1) The reflective mold projection aligner by one example of this invention is shown in drawing 1 . The laser beam 12 generated from the KrF excimer laser 11 is irradiated at a mask 3 through the beam plastic surgery optical system 13 and the illumination-light study system 2. The light which passed the mask

exposes a substrate 5 through the reflective mold contraction projection lens 7. Reflective mold reducing glass is a numerical aperture 0.3. By the Schwartz SHURUDO mold optical system, image formation of the mask 3 is carried out on a substrate 5. However, the optical system in drawing is typical strictly, and is not what showed the configuration of actual optical system faithfully. Here, the whole optical system from the injection side of an illumination-light study system to a substrate through a mask was installed in the interior of a liquid container 14, and into the liquid container, water was filled and it was filled up with the optical path with water.

[0015] Next, it is 0.35micromL/S as a result of imprinting the pattern of various dimensions using a projection aligner on the positive-resist film (PMMA, 1 micrometer of thickness) applied on Si substrate. The pattern has been formed. For the comparison, when water was removed from optical system and having been exposed in air, the resolution limit retreated to 0.5 micrometers.

[0016] In addition, the method of the wavelength of an aligner, the class of light source, and a projection lens and a numerical aperture, the class of medium, the resist process to be used, a mask pattern dimension, etc. are not limited to what was shown in this example. For example, a high-pressure mercury lamp and a xenon mercury lamp may be used instead of excimer laser. Moreover, into a liquid solution, it may replace with water and a perfluoroalkyl polyether etc. may be used. While this liquid was transparent on exposure wavelength, the sensitization property of a resist was not affected at all. Moreover, it may replace with PMMA also as a resist and a suitable novolak system positive resist, a chemistry multiplier system resist, etc. may be used.

[0017] (Example 2) The reflective mold projection aligner by the second example of this invention is shown in drawing 3 . The laser beam generated from ArF excimer laser (not shown) is irradiated at a mask 3 through beam plastic surgery optical system and an illumination-light study system (not shown). The light which passed the mask exposes a substrate 5 through the scanning catoptric system 21. Scanning catoptric system is numerical aperture 0.7. It is a step and scanning mold optical system, and image formation of the mask 3 is carried out on a substrate 5. However, the optical system in drawing is typical strictly, and is not what showed the configuration of actual optical system faithfully. Here, the field 22 shown with the slash in drawing within the optical path of projection optics was filled up with water.

[0018] Next, it is 0.11micromL/S as a result of imprinting the pattern of various dimensions using a projection aligner on the positive-resist film (PMMA, 1 micrometer of thickness) applied on Si substrate. The pattern has been formed. The resolution limit is 0.15 micrometers, when water was removed from optical system and it exposed in air for the comparison. It retreated and the effectiveness of this invention was checked.

[0019] (Example 3) In the projection aligner of an example 2, as shown in drawing 4 , the parallel plate 31 of a quartz divided the optical-system and substrate side. In order that the flow of the liquid medium produced when a substrate is scanned to optical system or a step feed is carried out by this might not attain to an optical-system side, the effect of fluctuation etc. of a refractive index was suppressed and the dimensional accuracy of a pattern improved. In addition, to the spherical aberration generated by quartz aperture insertion, it amended beforehand.

[0020] (Example 4) In the projection aligner of an example 2, as shown in drawing 5 , the quartz parallel plates 32 and 33 were formed between optical system and a substrate, and the liquid container was divided into the optical-system side liquid container 34 and the substrate side liquid container 35. Furthermore, it was made to perform the scan or step feed to the optical system of a substrate 5 the whole substrate side liquid container 35. Thereby, since the liquid flow near the substrate was also controlled, the effect of fluctuation etc. of a refractive index was suppressed and the dimensional accuracy of a pattern improved further.

[0021] In addition, when applying the configuration by this example to an example 1, the same device also as a mask side can be established.

[0022]

[Effect of the Invention] In case a pattern is imprinted on the above-mentioned substrate by carrying out image formation of the mask pattern to up to a substrate according to projection optics according to this invention, while the optical system containing a reflective mold lens constitutes projection optics By filling the whole optical path or a part of projection optics including between a substrate front face and projection optics with a medium with the bigger rate of specific refraction to the air in the wavelength of light than 1 Improvement in resolution equivalent to having short-wavelength-ized effectually simple can be aimed at without changing greatly the configuration and optical system of an aligner of a conventional type. Thereby, the resolution limit of optical lithography is improved about 30%, and it is 0.15 micrometers. It becomes

possible to form the following patterns.

[Translation done.]

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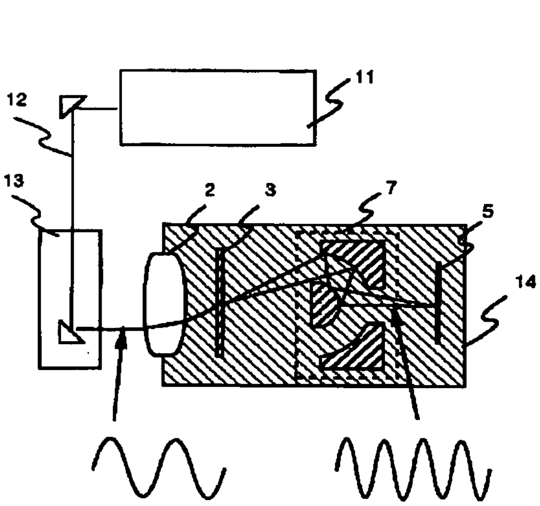
DRAWINGS

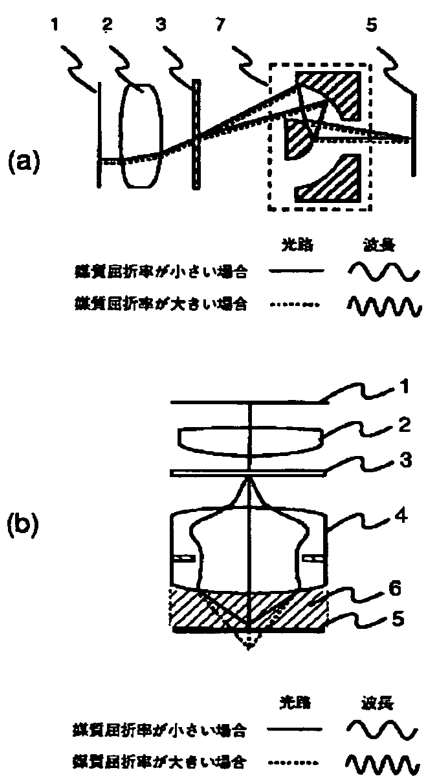
[Drawing 1]

図1



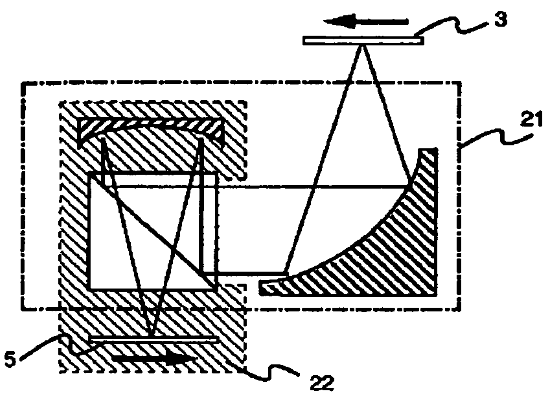
[Drawing 2]

図2



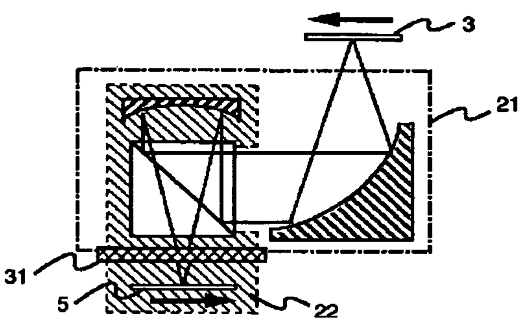
[Drawing 3]

図 3



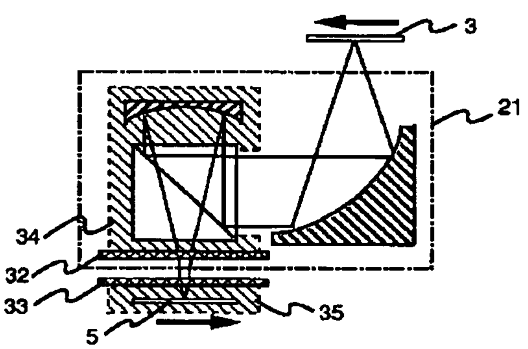
[Drawing 4]

図 4



[Drawing 5]

図 5



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		7352－4M		５１５　Ｄ	

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(71)出願人　000005108
株式会社日立製作所
東京都千代田区神田駿河台四丁目６番地

(72)発明者　福田　宏
東京都国分寺市東恋ケ窪１丁目280番地
株式会社日立製作所中央研究所内

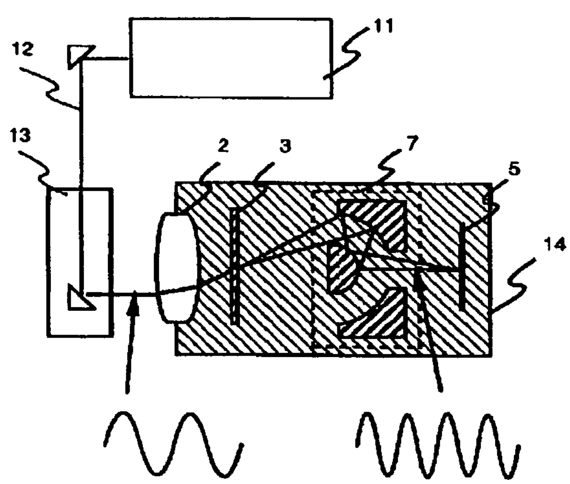
(72)発明者　田中　稔彦
東京都国分寺市東恋ケ窪１丁目280番地
株式会社日立製作所中央研究所内

(74)代理人　弁理士　小川　勝男

(54)【発明の名称】　パターン形成方法及びその露光装置

(57)【要約】
【構成】マスクパターン３を反射型レンズ７により基板５上へ結像させ、基板５の表面と反射型レンズ７の間を含む露光光学系の光路の全体又は一部を、露光波長における屈折率が１より大きな液体で満たす。
【効果】簡便に実効的に短波長化したのと同等の解像力向上効果を得ることができ、光リソグラフィの解像限界を３０％程度向上し、０．１５μｍ 以下のパターンを形成することができる。

図１



【特許請求の範囲】

【請求項１】光源を発した光を照明光学系を介してマスクに照射し、上記マスク上のパターンを投影光学系により基板上へ結像させることにより上記基板上にパターンを形成する方法において、上記投影光学系を反射型レンズを含む光学系により構成し、少なくとも上記基板と上記投影光学系の間を含む上記投影光学系の光路の全体又は一部を、上記光の波長における空気に対する比屈折率が１より大きな媒質で満たすことを特徴とするパターン形成方法。

【請求項２】請求項１において、上記媒質は液体であるパターン形成方法。

【請求項３】請求項２において、上記光の波長は１５０～２５０ｎｍであるパターン形成方法。

【請求項４】光源を発した光を照明光学系を介してマスクに照射し、上記マスク上のパターンを投影光学系により基板上へ結像させることにより上記基板上にパターンを形成する際に用いられる露光装置において、上記投影光学系を反射型レンズを含む光学系により構成し、上記基板と上記投影光学系の間を含む上記投影光学系の光路の全体又は一部を、上記光の波長における空気に対する比屈折率が１より大きな媒質で満たしたことを特徴とする投影露光装置。

【請求項５】請求項４において、上記投影光学系と前記基板の間に、透明な隔壁を設け、上記媒質を光学系側と基板側に分割する投影露光装置。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は、各種固体素子の微細パターンを形成するためのパターン形成方法、及びこれに用いられる投影露光装置に関する。

【０００２】

【従来の技術】ＬＳＩ等の固体素子の集積度及び動作速度を向上するため、回路パターンの微細化が進んでいる。現在これらのパターン形成には、量産性と解像性能に優れた縮小投影露光法が広く用いられている。

【０００３】図２（ｂ）に縮小投影露光法の光学系を模式的に示す。二次光源面上の有効光源１を発した光は照明光学系２を介してマスク３に照射され、マスク３上のパターンにより回折された光は縮小投影レンズ４により基板５上へ結像される。縮小投影レンズは通常屈折型レンズの組合せからなるものが用いられる。この方法の解像限界は露光波長に比例し、投影レンズの開口数（ＮＡ）に反比例するため、高ＮＡ化と短波長化により解像限界の向上が行われてきた。従来、露光光は、高圧水銀ランプのｇ線（波長４３６ｎｍ），ｉ線（波長３６５ｎｍ）が用いられてきたが、６４メガビットＤＲＡＭ以降回路寸法が光の波長より小さくなり、物理的限界に達している。

【０００４】一方、顕微鏡等の光学系の実効的なＮＡを

増大させる方法として、液浸(油浸)法が知られている。この方法は、レンズの先端と試料の間に空気より大きな屈折率ｎを有する液体（通常油を用いる）を充填することにより、実効的に光の波長を１／ｎとして解像度を向上させる。この方法の、光リソグラフィへの応用は、例えば、第５３回応用物理学会学術講演会講演予稿集，第２分冊，第４７２頁（１９９２年）に論じられている。

【０００５】一方、光リソグラフィ用の投影露光装置の別の形態として、ステップアンドスキャン方式等の反射型投影光学系を用いる方法が検討されている。この光学系は波長によらず最大０.７ 程度の大きなＮＡまで実現可能とされ、将来の露光装置として非常に有望である。この方式では、一部に屈折型光学素子を使用するものの色収差補正が可能なため、例えば、キセノン水銀ランプの２４５～２５３ｎｍという比較的広い波長領域で露光を行う。このため、従来の完全屈折型光学系を用いるエキシマレーザステッパの様な精密なレーザ波長スペクトルの狭帯域化と絶対波長の安定化を必要とせず、又、多重干渉効果と定在波効果を低減することができる。又、露光面積が広いことも実用上の大きな特長となっている。

【０００６】ステップアンドスキャン方式の光学系は、例えば、レジスト材料プロセス技術（技術情報協会，東京，１９９１年）第１２頁から第１４頁に論じられている。

【０００７】

【発明が解決しようとする課題】ところで、上記の従来液浸法で用いられる顕微鏡等の屈折型対物レンズは、レンズ先端と試料の間に所定の屈折率の液体を充填することを前提として専用に設計されたものである。この事情は投影露光用レンズの場合も同様であり、液浸対応の投影レンズは従来レンズとは全く異なる設計をもつ専用レンズとして特別に設計する必要がある。ここで、仮に液浸用以外の従来型屈折レンズの先端と基板（又は試料）の間の液体充填領域６（図２（ｂ）斜線部分）に屈折率ｎの液体を充填したとする。この場合、波長は実効的に１／ｎになるが、スネルの法則に従いレンズ先端における屈折角が減少するため、光線の光路は図２（ｂ）の破線の様に変化して実効的なＮＡが減少する。このため、必ずしも解像度は向上しない。しかも、ステッパ用レンズにおいて要求される広い露光面積を、液浸レンズ特有の大きなＮＡと両立させるのは極めて困難であるという問題があった。

【０００８】一方、光リソグラフィの解像度をさらに向上するには、露光波長をできるだけ短くすることが好ましい。しかし、従来型屈折光学系による露光法，反射型投影露光法のいずれも、光学材料の透過率の限界からＡｒＦエキシマレーザ（波長１９３ｎｍ）が実用的な短波長化の限界となってしまうという問題があった。

【０００９】本発明の目的は、従来型の露光装置の構成

と光学系を大きく変更することなく、簡便に実効的に短波長化したのと同等の解像力向上効果を得て、広い露光領域を確保しつつ投影露光法の解像度を極限まで向上することが可能なパターン形成方法を提供することにある。

【0010】

【課題を解決するための手段】上記目的を達成するため、本発明は、光源を発した光を照明光学系を介してマスクに照射し、上記マスク上のパターンを投影光学系により基板上へ結像させることにより上記基板上にパターンを形成する方法において、上記投影光学系を反射型レンズを含む光学系により構成し、少なくとも上記基板と上記投影光学系の間を含む上記投影光学系の光路の全体又は一部を、上記光の波長における空気に対する比屈折率が1より大きな媒質で満たす。

【0011】

【作用】図2（ａ）に示す反射光学系の光路全体を満たす媒質の屈折率を変化させることを考える。図2（ａ）は、図2（ｂ）における屈折型縮小投影レンズ4を反射型縮小投影レンズ7に置き換えたものである。図2（ａ）において、媒質の屈折率が小さい場合の光線の光路と大きい場合の光線の光路を各々実線と点線で示した。反射光学系中の光路は、反射の法則に従い反射レンズの表面形状のみによって決まり、媒質の屈折率によらない。従って、媒質の屈折率を変化させても、開口数等の光学系の幾何光学的な性質は何ら変化しない。一方、媒質として真空に対する比屈折率ｎの物質を用いると、波長は実効的に１／ｎとなる。この結果、実質的に波長だけが短くなったのと等しい効果が得られる。なお、図2（ａ）では簡単のため完全な反射光学系を仮定して説明したが、部分的には屈折光学系を用いもよい。

【0012】また媒質は、露光波長に対する屈折率ができるだけ大きいことが望ましく、十分な解像度効果を得るために、1.2 以上であることが望ましい。又、露光波長に対して実質的に透明で、かつ、光学素子及びレジストに悪影響を与えないことが望ましい。具体的には、例えば、水、又はアルコール，直鎖炭化水素等の有機溶媒，シリコーン樹脂、更に無機化合物又は有機化合物をこれらに溶解した液体、又、従来液浸顕微鏡や液浸屈折率測定法等において使用されている各種液体等を用いることができる。

【0013】なお、光学系中で媒質の温度や密度等のゆらぎにより屈折率が変化すると、光学系の結像特性に悪影響を及ぼす恐れがあるため、これら温度等は注意深く制御することが望ましい。特に、走査光学系では光学系に対して基板を走査するので、媒質の流れにより結像特性が変化しないように気を付けることが好ましい。

【0014】

【実施例】

（実施例１）本発明の一実施例による反射型投影露光装置を図1に示す。ＫｒＦエキシマレーザ１１から発生したレーザ光１２を、ビーム整形光学系１３及び照明光学系２を介してマスク３に照射する。マスクを通過した光は反射型縮小投影レンズ７を介して基板５を露光する。反射型縮小レンズは開口数０.３ のシュバルツシュルド型光学系で、マスク３を基板５上に結像させる。但し、図中の光学系はあくまで模式的なものであり、実際の光学系の構成を忠実に示したものではない。ここで、照明光学系の射出側からマスクを経て基板に至る光学系の全体を液体容器１４の内部に設置し、液体容器中に水を満たして光路を水で充填した。

【0015】次に、投影露光装置を用いて、Ｓｉ基板上に塗布したポジ型レジスト膜(PMMA,膜厚１μｍ）に様々な寸法のパターンを転写した結果、０.３５μｍL／Sパターンを形成できた。比較のため、光学系から水を除去し空気中で露光を行ったところ解像限界は０.５μｍに後退した。

【0016】なお、露光装置の波長，光源の種類，投影レンズの方式及び開口数，媒体の種類，使用するレジストプロセス，マスクパタン寸法等、本実施例に示したものに限定しない。例えば、エキシマレーザの代わりに、高圧水銀ランプやキセノン水銀ランプを用いてもよい。又、液体溶液中に水に代えて、パーフルオロアルキルポリエーテル等を用いてもよい。この液体は、露光波長に透明であるとともにレジストの感光特性に全く影響を与えなかった。又、レジストとしても、ＰＭＭＡに代えて適当なノボラック系ポジ型レジストや化学増幅系レジスト等を用いてもよい。

【0017】（実施例２）本発明の第二の実施例による反射型投影露光装置を図3に示す。ＡｒＦエキシマレーザ（図示せず）から発生したレーザ光を、ビーム整形光学系及び照明光学系（図示せず）を介してマスク３に照射する。マスクを通過した光は走査型反射光学系２１を介して基板５を露光する。走査型反射光学系は開口数０.７ のステップアンドスキャン型光学系で、マスク３を基板５上に結像させる。但し、図中の光学系はあくまで模式的なものであり、実際の光学系の構成を忠実に示したものではない。ここで、投影光学系の光路内の図中斜線で示した領域２２に水を充填した。

【0018】次に、投影露光装置を用いて、Ｓｉ基板上に塗布したポジ型レジスト膜(PMMA,膜厚１μｍ）に、様々な寸法のパターンを転写した結果、０.１１μｍL／S パターンを形成できた。比較のため、光学系から水を除去し空気中で露光を行ったところ、解像限界は０.１５μｍ に後退し、本発明の効果が確認された。

【0019】（実施例３）実施例２の投影露光装置において、図4に示す様に光学系側と基板側とを石英の平行平板３１により分割した。これにより、基板を光学系に対して走査したりステップ送りしたときに生じる液体媒質の流れが光学系側に及ぶことがないため、屈折率の揺

らぎ等の影響が抑えられてパターンの寸法精度が向上した。なお、石英窓挿入により発生する球面収差に対しては、あらかじめ補正を行った。

【００２０】（実施例４）実施例２の投影露光装置において、図５に示す様に光学系と基板の間に石英平行平板３２，３３を設け、液体容器を光学系側液体容器３４と基板側液体容器３５に分割した。更に基板５の光学系に対する走査又はステップ送りを、基板側液体容器３５ごと行うようにした。これにより、基板近傍での液体の流れも抑制することができるため、屈折率の揺らぎ等の影響が抑えられてパターンの寸法精度が更に向上した。

【００２１】なお、本実施例による構成を実施例１に適用する場合、マスク側にも同様の機構を設けることができる。

【００２２】

【発明の効果】本発明によれば、マスクパターンを投影光学系により基板上へ結像させることにより上記基板上にパターンを転写する際、投影光学系を反射型レンズを含む光学系により構成するとともに、基板表面と投影光学系の間を含む投影光学系の光路の全体又は一部を、光の波長における空気に対する比屈折率が１より大きな媒質で満たすことにより、従来型の露光装置の構成と光学系を大きく変更することなく、簡便に実効的に短波長化したのと同等の解像力向上を図ることができる。これにより、光リソグラフィの解像限界を３０％程度向上し、０．１５μｍ 以下のパターンを形成することが可能となる。

【図面の簡単な説明】

【図１】本発明の原理の説明図。

【図２】本発明の一実施例による露光装置の説明図。

【図３】本発明の第二の実施例による露光装置の説明図。

【図４】本発明の第三の実施例による露光装置の説明図。

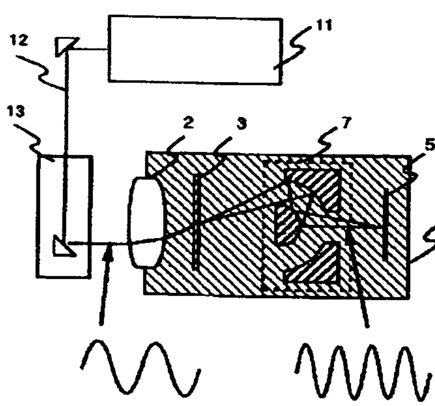
【図５】本発明の第四の実施例による露光装置の説明図。

【符号の説明】

２…照明光学系、３…マスク、５…基板、７…反射型縮小投影レンズ、１１…エキシマレーザ、１２…レーザ光、１３…ビーム整形光学系、１４…液体容器。

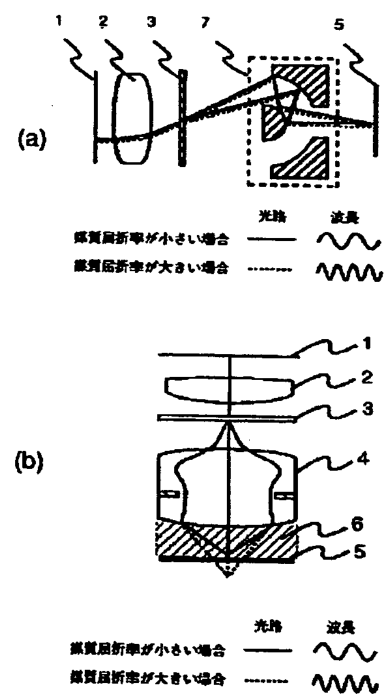
【図１】

図1



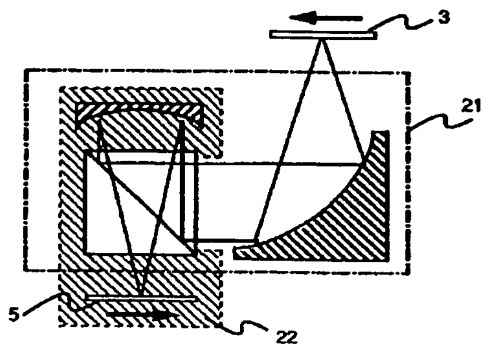
【図２】

図2



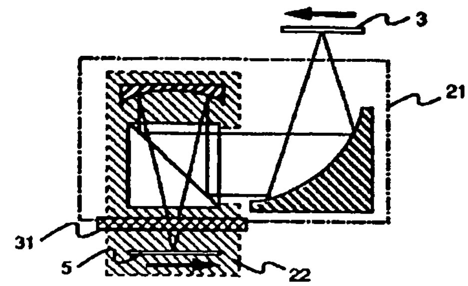
【図3】

図3



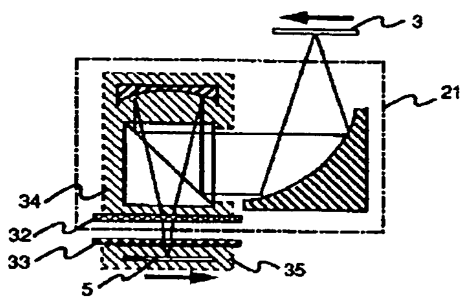
【図4】

図4



【図5】

図5



[Title of the Invention] PATTERN FORMING METHOD AND EXPOSURE APPARATUS FOR USE IN SUCH METHOD

[ABSTRACT]

[Summary]

[Constitution] A mask pattern (3) is imaged on a substrate (5) by using a reflective lens (7) and all or a part of an optical path of an exposure optical system including a space between the surface of the substrate (5) and the reflective lens (7) is filled with a liquid whose refractive index at an exposure wavelength is 1 or greater.

[Effect] It is possible to achieve an effect of improving resolution equivalent to reducing a wavelength easily and effectively so as to improve the resolution limit of optical lithography by the order of 30%, whereby a 0.15 μm or smaller pattern can be formed.

[Scope of Claims for Patent]

[Claim 1] A pattern forming method of forming a pattern on a substrate by irradiating a mask with light emitted from a light source via an illumination optical system to image the pattern on the mask onto the substrate using a projection optical system, wherein the projection optical system is composed of an optical system including a reflective lens and wherein all or a part of an optical path of the projection optical system including at least a space between the substrate and the projection optical system is filled with a medium whose refractive index relative to that of air at the wavelength of the light is 1 or greater.

[Claim 2] The pattern forming method according to claim 1, wherein the medium is a liquid.

[Claim 3] The pattern forming method according to claim 2, wherein the wavelength of the light is of 150 to 250 nm.

[Claim 4] A projection exposure apparatus for use in forming a pattern on a substrate by irradiating a mask with light emitted from a light source via an illumination optical system to image the pattern on the mask onto the substrate using a projection optical system, wherein the projection optical system is composed of an optical system including a reflective lens and wherein all or a part of an optical path of the projection optical system including a space between the substrate and the projection optical system is filled with a medium whose refractive index relative to that of air

at the wavelength of the light is 1 or greater.

[Claim 5] The projection exposure apparatus according to claim 4, wherein a transparent partition is interposed between the projection optical system and the substrate to divide the medium into optical system side and substrate side.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to a pattern forming method for forming a fine pattern of various kinds of solid state components and a projection exposure apparatus for use in such method.

[0002]

[Background Related Art]

For the purpose of improving the degree of integration and the operating speed of LSI or other solid state components, miniaturization of a circuit pattern progresses. Currently, a reduction projection exposure method, which is superior in mass productivity and resolution performance, is widely used for their pattern formations.

[0003]

FIG. 2(b) schematically shows an optical system in the reduction projection exposure method. Light emitted from an effective light source 1 on a secondary light source plane is applied to a mask 3 via an illumination optical system 2 and the light diffracted by a pattern on the mask 3 forms an image onto a substrate 5 by means of a reduction projection

lens 4. The reduction projection lens used here is generally made of refractive lenses combined. Since the resolution limit of this method is in proportion to an exposure wavelength and in inverse proportion to the numerical aperture (NA) of a projection lens, the resolution limit has been improved by increasing the NA and decreasing the wavelength. Conventionally, a g-ray (wavelength: 436 nm) or i-ray (wavelength: 365 nm) of a high-pressure mercury lamp have been used as exposing light. The circuit, however, becomes smaller than the wavelength of light after the production of 64-megabit DRAM, and therefore this method has reached the physical limitation.

[0004]

On the other hand, there is known an (oil) immersion method as a method of effectively increasing NA of a microscope or any other optical system. This method effectively improves the resolution by decreasing the wavelength of light to 1/n by filling the space between the end of a lens and a sample with liquid (generally oil is used) having a higher refractive index n than air. The application of this method to optical lithography is described, for example, in the digest of the 53rd annual meeting of the Japan Society of Applied Physics, Vol. 2, pp.472 (1992).

[0005]

On the other hand, there has been studied a method using a reflective projection optical system in a step-and-

scan mode or the like in another form of the projection exposure apparatus for optical lithography. This optical system is recognized to be capable of achieving high NA of the order of max. 0.7 independently of the wavelength and therefore it is very promising as a future exposure apparatus. This system performs exposure in a relatively wide wavelength region, for example, of 245 to 253 nm of a xenon mercury lamp since chromatic aberration can be corrected though refractive optical elements are partially used. Accordingly, it does not require a narrow band of a precise laser wavelength spectrum nor a stable absolute wavelength, which will be required by a conventional excimer laser stepper using a completely refractive optical system, and can reduce the multiple interference effect and the standing wave effect. Moreover, the wide exposed area is a remarkable feature from a practical viewpoint.

[0006]

The step-and-scan optical system is discussed, for example, in "Resist Material Process Technology" (Technical Information Institute Co., Ltd., Tokyo, 1991, pp.12 to 14).

[0007]

[Problems to be Solved by the Invention]

The microscope or other refractive objective lens for use in the conventional immersion method is designed exclusively therefor on the premise that the space between the end of the lens and a sample is filled with liquid having a given refractive index. This condition is the same as in a

projection exposure lens. Therefore, the projection lens for liquid immersion need be particularly designed as a dedicated lens with a quite different design from that of the conventional lens. It is assumed here that a liquid filling space 6 (the shaded area in FIG. 2(b)) between the end of the conventional refractive lens other than a refractive lens for liquid immersion and a substrate (or a sample) is filled with a liquid having a refractive index n. In this instance, the wavelength decreases to 1/n effectively, but the angle of refraction at the end of the lens decreases according to Snell's law and therefore the optical path of the beam of light changes as indicated by a dashed line in FIG. 2(b), by which the effective NA decreases. Therefore, the resolution is not necessarily improved. Moreover, there has been a problem that it is extremely hard to satisfy both of the wide exposed area, which is required in a stepper lens, and the high NA specific to the immersion lens.

[0008]

On the other hand, it is preferable to decrease an exposure wavelength as much as possible in order to further improve the resolution of the optical lithography. In both of the exposure method using the conventional refractive optical system and the reflective projection exposure method, however, there has been a problem that an ArF excimer laser (wavelength: 193 nm) provides a practical limit to achieving a short wavelength due to the limitation in transmittance of optical materials.

[0009]

Therefore, an object of the present invention is to provide a pattern forming method capable of improving the resolution of a projection exposure method to the maximum while securing a wide exposed area by achieving an effect of increasing the resolution equivalent to reducing a wavelength easily and effectively, without significantly changing the configuration of the conventional exposure apparatus and the conventional optical system.

[0010]

[Means to Solve the Problem]

To achieve the above object according to an aspect of the present invention, there is provided a pattern forming method of forming a pattern on a substrate by irradiating a mask with light emitted from a light source via an illumination optical system to image the pattern on the mask onto the substrate using a projection optical system, wherein the projection optical system is composed of an optical system including a reflective lens, and wherein all or a part of an optical path of the projection optical system including at least a space between the substrate and the projection optical system is filled with a medium whose refractive index relative to that of air at the wavelength of the light is 1 or greater.

[0011]

[Operation of the Invention]

The following examines the situation of changing a

refractive index of a medium for filling all of an optical path of a reflective optical system shown in FIG. 2(a). FIG. 2(a) shows a system in which a reflective reduction projection lens 7 is used instead of a refractive reduction projection lens 4 shown in FIG. 2(b). In FIG. 2(a), a solid line and a dashed line indicate optical paths of beams of light observed when the refractive index of the medium is low and it is high, respectively. The optical path within the reflective optical system is determined only by the surface shape of the reflective lens according to the law of reflection, and it is independent of the refractive index of the medium. Therefore, a change in the refractive index of the medium does not change geometrical-optical characteristics of the optical system including NA. On the other hand, if a material of a refractive index n relative to vacuum is used as the medium, the wavelength effectively decreases to 1/n. As a result, it is possible to achieve the same effect as in the case where only the wavelength is reduced substantially. While the description has been made with reference to FIG. 2(a) on the assumption that the complete reflective optical system is used for simplification, it is also possible to partially use a refractive optical system.

[0012]

The medium preferably has as high refractive index as possible to the exposure wavelength and preferably has a refractive index of 1.2 or greater in order to obtain a

sufficient resolution effect. Moreover, preferably the medium is substantially transparent to the exposure wavelength and does not adversely affect optical elements and resist. More specifically, it is possible to use, for example, water or alcohol, organic solvent including straight-chain hydrocarbon, silicone resin, or a liquid obtained by dissolving inorganic compound or organic compound in these, or any of various liquids conventionally used for an immersion microscope or in an immersion refractive index measurement method.

[0013]

If the refractive index changes due to fluctuation in temperature, density, or the like of the medium in the optical system, it could lead to an adverse effect on an imaging characteristic of the optical system. Therefore, it is preferable to control the temperature and the like carefully. Particularly, since a substrate is scanned relative to the optical system in a scanning optical system, it is preferable to see to it that the imaging characteristic is not changed by the flow of the medium.

[0014]

[Embodiment]

(First embodiment)

Referring to FIG. 1, there is shown a reflective projection exposure apparatus according to one embodiment of the present invention. A mask 3 is irradiated with a laser beam 12 emitted from a KrF excimer laser 11 via a beam

forming optical system 13 and an illumination optical system 2. A substrate 5 is exposed to light, which has passed through the mask, via a reflective reduction projection lens 7. The reflective reduction projection lens, which is a Schwarzschild-type optical system of 0.3 NA, forms an image of the mask 3 onto the substrate 5. Note here that the optical system in the diagram is only schematic and it does not faithfully represent the configuration of a practical optical system. In this condition, the entire optical system from the emission side of the illumination optical system via the mask to the substrate is placed inside a liquid container 14 and the liquid container 14 is filled with water so as to fill the optical path with water.

[0015]

Subsequently, patterns of various sizes are transferred to a positive resist film (PMMA, 1 μm of film thickness) applied to a Si substrate by using the projection exposure apparatus. As a result, a 0.35 μm L/S pattern has been formed successfully. For comparison, the exposure is performed in the air after draining the water from the optical system. Consequently, the resolution limit has been deteriorated to 0.5 μm.

[0016]

The wavelength of the exposure apparatus, the type of the light source, the feature and NA of the projection lens, the type of medium, a resist process to be used, a mask pattern size, and the like are not limited to those described

in this embodiment. For example, a high-pressure mercury lamp or xenon mercury lamp can be used instead of the excimer laser. Moreover, perfluoroalkylpolyether or the like can be used instead of water for the liquid solution. This liquid is transparent to the exposure wavelength and did not affect the photosensitive characteristics of the resist at all. In addition, an appropriate novolac positive resist or chemical amplification resist can be used instead of PMMA as a resist.

[0017]

(Second embodiment)

Referring to FIG. 3, there is shown a reflective projection exposure apparatus according to a second embodiment of the present invention. A mask 3 is irradiated with a laser beam emitted from an ArF excimer laser (not shown) via a beam-shape forming optical system and an illumination optical system (not shown). A substrate 5 is exposed to light, which has passed through the mask, via a scanning reflective optical system 21. The scanning reflective optical system, which is a step-and-scan optical system of 0.7 NA, forms an image of the mask 3 onto the substrate 5. Note here that the optical system in the diagram is only schematic and it does not faithfully represent the configuration of a practical optical system. In this condition, a shaded area 22 within the optical path of the projection optical system in the diagram indicates a space filled with water.

[0018]

Subsequently, patterns of various sizes are transferred to a positive resist film (PMMA, 1 μm of film thickness) applied to a Si substrate by using the projection exposure apparatus. As a result, a 0.11 μm L/S pattern has been formed successfully. For comparison, the exposure is performed in an air medium after draining the water from the optical system. Consequently, the resolution limit has deteriorated to 0.15 μm and thus the effect of the present invention has been confirmed.

[0019]

(Third embodiment)

In the projection exposure apparatus of the second embodiment, the medium is divided into optical system side and substrate side by a parallel plate 31 of quartz as shown in FIG. 4. This prevents the flow of the liquid medium from reaching the optical system side, which will occur when the substrate is scanned or step-fed relative to the optical system. Therefore, the effect of the fluctuation in the refractive index is limited, whereby the pattern size accuracy is improved. Note here that a spherical aberration caused by opening a quartz window is previously corrected.

[0020]

(Fourth embodiment)

Quartz parallel plates 32 and 33 are interposed between the optical system and the substrate as shown in FIG. 5 in the projection exposure apparatus of the second embodiment to divide the liquid container into an optical

system side liquid container 34 and a substrate side liquid container 35. Moreover, the scanning or step-feed of the substrate 5 relative to the optical system is performed for each substrate side liquid container 35. This suppresses the flow of the liquid in the vicinity of the substrate and therefore reduces effects of the fluctuation in refractive index or the like, which further improves the pattern size accuracy.

[0021]

If the configuration of this embodiment is applied to the first embodiment, the same mechanism can be placed also on the mask side.

[0022]

[Effect of the Invention]

According to the present invention, when a pattern is transferred to a substrate by imaging a mask pattern onto the substrate by using a projection optical system, the projection optical system is composed of an optical system including a reflective lens and all or a part of an optical path of the projection optical system including a space between the surface of the substrate and the projection optical system is filled with a medium whose refractive index relative to that of air at the wavelength of light is 1 or greater. This enables an improvement of resolution equivalent to reducing a wavelength easily and effectively, without significantly changing the configuration of the conventional exposure apparatus and the conventional optical

system. This improves the resolution limit of the optical lithography by the order of 30%, by which it is possible to form a 0.15 μm or smaller pattern.

[Brief Description of the Drawings]

[Fig. 1]

It is an explanatory diagram of the principle of the present invention.

[Fig. 2]

It is an explanatory diagram of an exposure apparatus according to one embodiment of the present invention.

[Fig. 3]

It is an explanatory diagram of an exposure apparatus according to a second embodiment of the present invention.

[Fig. 4]

It is an explanatory diagram of an exposure apparatus according to a third embodiment of the present invention.

[Fig. 5]

It is an explanatory diagram of an exposure apparatus according to a fourth embodiment of the present invention.

[Explanation of the Reference Numerals]

2 Illumination optical system

3 Mask

5 Substrate

7 Reflective reduction projection lens

11 Excimer laser

12 Laser beam

13 Beam-shape forming optical system

14 Liquid container